Who pulls the strings behind the scenes?

Analysing power structures of international media finance networks with innovative graph-based methods

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Abstract

Media companies face competitive market environments characterised by an enormous variety of highly dynamic network structures. Two challenges have to be overcome for their analysis: data is often incomplete and/or noisy and already smaller network analyses are difficult problems to solve, even with computer assistance. Regarding ownership and finance studies specific to media companies there is a very limited amount of literature. This paper uses a multidisciplinary case study approach to investigate previous and new patterns and the underlying dynamics in media investment and finance. The application of novel network algorithms to finance networks can detect clusters of network participants, e.g. shareholders who have invested in media companies, and assist in predicting their behaviour and potential communication patterns.

1. Introduction

The competitive market environments of media companies are characterised by an enormous variety of highly dynamic networks structures. Examples include social networks in digital communication markets, links between owners and/or managers or the networks on capital markets. Well-founded estimates regarding the participants, structures and fluctuations of these networks become progressively more difficult to determine with increasing lengths of planning horizons. Therefore, adequate and reliable methods for short- as well as long-term predictions of potential changes of their surrounding network environments support companies in generating competitive advantages.

Scientific disciplines approach the research area of networks from different angles. Biology, medicine or engineering have already applied existing graph-based algorithms in a vast number of research and application projects. Economics develops a number of network-related theoretic approaches for market structures, information distribution, property rights dissemination or network effects.

Opposed to that, graph-based analysis in media management or other fields of business administration (with the exception of production management and logistics) is still in its early stages. So far, management science has preferred qualitative descriptions of networks or their visualisation. Definite answers to entrepreneurial problems resulting from network structures were limited due to incomplete or noisy data[1] or by missing calculation technologies. However, with network analysis becoming increasingly relevant for managerial decision making, companies expect computer and management science to provide algorithms and methods for solving these problems, thus enhancing management information systems for companies.

Two important aspects challenge research as well as practical applications of social network structures and information flows: On the one hand data is often incomplete and/or noisy, and on the other hand network analyses, even for smaller networks with less than ten participants or components, are instances of so-called polynomial complete problems[2], i.e. problems for which there exists no polynomial-time algorithm computing an optimal solution. This means it is well-known in computer science that these network analyses are inherently difficult, even for small networks, because solutions cannot be calculated within an adequate timeframe.

In practical applications of social network analysis even solutions whose resulting values may not be optimal but closely approximate the optimum could already significantly improve the status quo for rapid but still focused response. The objective therefore lies in developing

[1] The expression „noisy data“ is used in statistics to characterise deviations due to inexact measurement devices or recording procedures as well as statistical variations of the measured quantities.

[2] Computational complexity theory calls such a problem NP-hard (non-deterministic polynomial-time hard). It refers to a class of problems for which, even in theory, no shortcut or smart algorithm is possible that would lead to a simple or rapid solution. Instead, the only way to find an optimal solution is a computationally-intensive, exhaustive analysis, in which all possible outcomes are tested.

effective heuristics for media management that identify pointless variants and exclude them from further analysis in order to reduce the complexity of the problem. Theoretical computer science has developed innovative methods and procedures to solve problems on networks and has generally proven their functionality. Nevertheless, the heuristics for network problems need to be evaluated regarding their quality in the decision making processes of media companies and their application depends on their eventual inclusion into methods of strategic planning.

This paper uses a multidisciplinary case study approach to investigate patterns as well as the underlying dynamics in dynamics in media investment and finance. The objective is to extract relevant formations and evaluate their specific attributes. This paper presents a novel idea using so-called weighted quasi-bicliques to find dense places of connectivity in network structures. This helps in extracting missing company-company interactions from relationship data which is an improvement over previous approaches.

2. Social Networks and Network Analysis

The research on the analysis and modelling of networks as well as networked dynamical systems has seen a steep increase in a large variety of disciplines ranging from physics, mathematics, computer science, biology, and economics to sociology. Watts gives an extensive overview of the major findings and relates them with previous work in the social and mathematical sciences (Watts, 2004, pp. 243–264). However, publication in the area of enterprise social networks is still relatively scarce (Smith, Hansen, & Gleave, 2009, p. 706). The following chapter gives a brief overview of social networks and network analysis.

2.1. Definition of Terms

A *social network*[3] can be represented through a social graph consisting of a set of nodes linked by so-called edges (Smith, Hansen, & Gleave, 2009, p. 706). Nodes can represent persons, organisations or states, the edges the flows (e.g. of friendship, trade, military engagement) between them (Podolny & Page, 1998, p. 59). If an edge simply indicates that a relationship exists between two nodes it is called undirected. For hierarchies between two nodes, i.e. if one member influences another, the direction can be represented by a directed graph (Podolny & Page, 1998, p. 59). The amount of information or the intensity of the influence is added by labelling the respective edge. Another significant key figure is the *completeness* of the network. It indicates the number of existing links in relation to the maximum number of links in a network (if all nodes were linked with each other). The higher the completeness the faster information can spread in a particular network. Besides the number of links their form plays an important role because the stronger two participants are connected, e.g. through similarities in their wants, the higher the probability of passing on information and/or exerting influence.

In a *unimodal network* only nodes (or vertices) of one type are linked together. For example, the network graph connects people with people, companies with companies or objects with objects. *Multimodal* networks also link nodes representing different entities, therefore people, companies and objects could exist in the same network graph. A common example is a bimodal graph connecting people to a set of similar objects. Regarding the properties of their ties (or edges) networks differ in a number of ways. *Direct* graphs refer to explicit connections, e.g. of people. In *indirect* graphs the connection is via an implicit relationship, e.g. if two people visited the same place. In *symmetric* relationships the connection is

[3] Only terms used in this paper are explained in this section. For extensive explanations of other terms and definitions relating to social networks see Easley & Kleinberg (2010, part 1) and Jackson (2008, p. 20-53).

reciprocal, so A is a friend of B and B is a friend of A. In *asymmetric* links the connection is not reciprocated because A may follow B on Twitter but not vice versa. Edges can be differentiated by attaching a weight that represents the intensity of the tie, for example how often someone bought a particular product or how many messages were passed between two entities (Smith et al., 2009, pp. 706–707).

Cliques in a network are dense sub-networks in which each node is linked to every other node (Marsden, 1990, p. 453). As members of cliques often behave similarly, they are of great interest for network analysis (Ward et al., 2011, p. 250). *Clustering* then measures the extent to which a graph contains locally dense clusters or nodes by assessing the probability that two associates of a node are also connected.

Social network analysis has emerged as a key technique in modern sociology. It uses network and game theory applications to investigate the structures of social networks and the behaviour of networks and/or their participants and predict emerging structures (Easley & Kleinberg, 2010, 7-9; Jackson, 2008, 3).

2.2. Objective and Method

The objective of social network analysis is to explain social behaviour or the formation and evolution of institutions by investigating the relationships between concrete entities such as persons or organisations through finding patterns, changes and implications of these relationships. The two general categories to be derived from network graphs are features characterising the whole network's structure (e.g. density, signs of hierarchies, fragmentation, gaps) and features describing the network position of particular nodes (e.g. central, highly connected, peripheral, gate-keeper to other nodes) (Ward, Stovel, & Sacks, 2011, p. 246). Besides investigating relationships between actors, network analysis regards the actors and their actions as interdependent rather than autonomous units. The connections between network participants constitute flows of material and/or non-material resources (Wasserman & Faust, 2009, p. 4). The derived network models describe structures, i.e. emerging patterns, of the economic, political and/or social relations between participants. These structures as well as the others' activities provide individuals in the networks with both opportunities and restrictions for actions (Ward et al., 2011, p. 246). However, network analysis typically does not focus on individuals but concerns smaller (dyads, triads) and larger structures (subgroups of individuals) or complete networks (Wasserman & Faust, 2009, p. 4).

Analysis of networks can be done through either visualisation (for small networks) or by applying network analytic software which allows for a deeper investigation of the structural properties (Scott, 1991, p. 183). Visualisation of networks can reveal important nodes or properties especially if they reflect in easily recognisable colours or sizes of nodes combined with network metrics (e.g. degree). This also helps to detect changes over time when visualisations for different moments are compared (Smith et al., 2009, p. 705). However, visualisation is not a feasible method for larger and more complex networks (Smith et al., 2009, p. 709) which are the norm rather than the exception. This means visualisation is often not a viable option.

Network analytic tools are used to represent the social graph of a network (nodes and edges) and to analyze the network data assisted by computers. With these tools larger structures can be investigated that would defy visualisation. Network analytic tools apply algorithms (calculation methods) from graph and game theory to detect patterns and predict future developments of networks.

Unfortunately searches for patterns in networks are among the most difficult in computer science. Metaphorically, exploring unknown environments can be compared to the situation where a newborn child discovers its new surroundings while trying to memorise the places and proportions of obstacles while the objects are being moved (Deng, Kameda, &

Papadimitriou, 1998, p. 215). Finding shortest paths, matchings, clusters etc. in network structures requires an algorithm that is efficient, i.e. finds the solution in minimal time. The problem with network exploration is that it entails searching for a solution from among an exponential population of possibilities because whenever a node is added the number of possible links grows exponentially. So for calculations this means checking every possible link (exhaustive search) takes exponential time, i.e. forever, as long as the network grows (Dasgupta, Papadimitriou, & Vazirani, 2008, p. 247).

There is an ongoing quest for efficient algorithms by finding intelligent ways to circumvent this process of exhaustive search by discovering ways to narrow down the search space. This is like determining locations in the dark room where the obstacles are more likely to be. These types of problems are known to be inherently "hard", i.e. difficult.

Besides algorithmic limitations, collecting and interpreting empirical data bears additional challenges. Collecting data on social networks is difficult and there is an ongoing debate as the current instruments (e.g. questionnaires, interviews) do not measure actually existing social relations but only subjective perceptions by the actors (Marsden, 1990, p. 437). One way to reduce this is by using co-orientation analysis to test for congruency. It has to be determined how to deal with temporal elements as social structures fluctuate and there is definitely no fully persistent order or pattern. Although there is agreement that the dynamics must be captured both by the data and the metrics, research is still in its early stages. Social relationships bear another inherent challenge as their exact start, change and end is hard to capture (Marsden, 1990, p. 437).

Network analysis can only detect complete structures in networks provided the empirical data accurately reflects the totality of connections (as either existent or non-existent) between any two nodes. However, in practice this is rarely the case as data is typically incomplete and/or partially distorted (Ward et al., 2011, pp. 247–248). Furthermore, most tasks require a clear determination of the boundary of the relevant population (Ward et al., 2011, p. 255) which is in dynamic settings is difficult to trace. The implications are serious as the outcome of the analysis highly depends on the data quality. For example, network centrality of a node can only be assessed if all data regarding a central actor is available (Ward et al., 2011, pp. 247–248).

Moreover, when interpreting empirical data regarding patterns in social networks it is important to realise that besides the obvious connections, underlying abstract structures exist whose links describe intangible interactions on the social process level. These connections are much harder to find and even harder to interpret. For example, how is the link between two people different when they co-author an article or when they sit on the same board of directors? (Watts, 2004, 253). Following this general overview the next chapter addresses the role of network analysis in concepts of economics and business management.

3. Networks and Corporations

Interest into studying network structures in economics and business management was spurred by sociological critique of markets and hierarchies as organisational forms (Podolny & Page, 1998, p. 57). Companies use evolving networks in which they interact with other firms to strengthen profitable relations, to form new and to delete unfavourable ones. This approach differs considerably from the standard neoclassical model in which autonomous omniscient actors decide independently only using the price as a criterion. The model also assumes complete knowledge of the entire market (actors, goods, prices, etc.) and no costs for coordination. For large systems both assumptions become quite unrealistic. The network model can incorporate both, bounded rationality and transaction costs[4] (Blum, 2010, pp. 304–

[4] To use external providers companies have to negotiate contracts and control the fulfilment of agreements. The costs incurred for these transactions, Coase (1960, p. 8) appropriately named "transaction costs". They are a central element of the school of the New Institutional Economics. If transaction costs are lower than costs of

305; Kleinaltenkamp & Ehret, 2009, pp. 46–47; König & Battiston, 2009, p. 24).

So far applications of social network analysis for corporations have dealt with questions of corporate ownership and board of directors, diffusion of information in networks, formal and informal organisations, and R&D collaborations (König & Battiston, 2009, pp. 25–27). Questions investigated in studies about the company environment concern drivers and processes of strategic network formation and development, types of inter-company links that improve competitive positions, sources of value creation in networks, and linkages between distribution of benefits depending on companies' positions in the network (Chan-Olmsted, 2006, pp. 47–48). Researchers focussing on internal company structures have studied the different roles of individuals within organizations, existing subgroups, connections between organizational divisions, finding bridge roles that connect otherwise unconnected groups, contact conversion to adopt a new technology or practices, or changes of the structures of an enterprise’s social networks change after a particular event (e.g., a company social; a round of new hires or layoffs) (Smith et al., 2009, p. 708).

Of particular interest in the scope of this paper are the formation and development of strategic company networks. Strategic networks may be defined as stable relationships between two or more organisations which are strategically important to participating companies. Links can take the form of joint ventures, alliances or other long-term partnerships, e.g. buyer-supplier relations, equity alliances, distribution agreements. Equity joint firms and minority equity alliances are grouped as equity alliances whereas relationships without equity exchange are called non-equity alliances (Chan-Olmsted, 2006, p. 46). Opportunities for strategic cooperation are manifold: achieving critical mass (e.g. for negotiations), cost pooling, generating economies of scale and/or scope, creation of synergies, risk spreading and sharing, accessing new customers, markets, information, technologies or suppliers, developing

internal production companies will acquire a good or service through the market. Another implication of Coase's ideas is that companies need to manage the network of specialised providers by installing an institutional framework and thus reduce uncertainty (Coase, 1960, pp. 6–44).

industry standards, sharing knowledge and facilitating, aligning resources for large scale projects, increasing speed in product development or market entry, preparations for an acquisition, image improvement, control of competition or improving the competitive position (Blum, 2010, p. 303; Bronner & Mellewigt, 2001, pp. 730–734; Glaum, Hommel, & Thomaschewski, 2003, p. 828). Disadvantages involve the costs for managing the network, limited/partial control of the network structures, loss of competencies and increasing interdependencies (Achtenhagen & Norbäck, 2010, pp. 53–56, Blum, 2010, p. 305). Being connected has advantages; studies have shown that there is a positive correlation between the diversity of its alliance network and a firm's performance (Podolny & Page, 1998, p. 63).

The patterns of socio-economic networks are determined both by the formation of new and the persistence of existing ties as well as the constraints for both of them. On the rational surface it seems that connections are only established if the participants gain more from a relationship than the costs incurred for creating and managing it (König & Battiston, 2009, p. 52). However, studies have demonstrated that “the probability that an alliance will form between two actors is a function of the indirect connections that these actors have to one another. These indirect connections are conduits for information about reputation and peer control” (Podolny & Page, 1998, p. 73). Social ties provide a mechanism by which actors obtain information through trusted sources, possibly combined with a social obligation to them, that helps to overcome information asymmetries and hence to pursue business opportunities that would not have been available or for which risk assessment might have been too difficult (Shane & Cable, 2002, p. 380).

The strength of ties is a combination of social closeness, degree of mutuality and frequency of contact. While strong ties are the socially closer with high flows of goods, emotions, information etc., it is the weak ties that according to Granovetter connect otherwise separate parts of the network structures (Granovetter, 1973, p. 1361). The use of these weak ties to access more remote parts of the network is of vital importance in corporate environments (Cyganski & Haas, 2011, p. 104). Already established ties affect a company's ability to form new ties which means there is an incentive to maintain ties even if they are currently not being actively used (Podolny & Page, 1998, p. 70). Besides, potential costs of withdrawal stabilise network ties (König & Battiston, 2009, p. 52) and may even create a lock-in situation. Thus, trust and obligations not only determine the successful operation of networks and also limit the extent of changes to the network (Podolny & Page, 1998, p. 61 and 70). Another restrictive factor for the choice of partners is status. In particular in markets with a high level of uncertainty regarding the quality of service, a participant's low status could limit his access to potential affiliates. The boundary is enforced as high status actors could damage their own reputation if they link up with low status actors (Podolny & Page, 1998, p. 69).

Communication in social networks bears some special characteristics. „The most useful information is rarely that which flows down the formal chain of command in an organization, or that which can be inferred from price signals. Rather, it is that which is obtained from someone you have dealt with in the past and found to be reliable“ (Powell, 1990, p. 304). Thus, recommendations diffused between partners in a network are typically considered very trustworthy (Bodendorf & Kaiser, 2009, p. 65). As a consequence, negative reports on companies have an increased dangerous potential because reduced trust in their organisation, products, services, brands etc. could damage both reputation and status (Standop & Grunwald, 2009, p. 229) with serious effects on their network position and influence.

In the analysis of corporate networks in particular the social relations existing between companies are of interest as they can be regarded as networks of power. Both ownership relations between firms as well as so called interlocking directorships form intricate networks. Interlocks occur when a person affiliated with one organisation has a seat on the board of directors of another organisation (Mizruchi, 1996, p. 271). On one hand ownership relations are instruments to exert direct corporate control but ownership relations can also be indirect and there exist patterns such as the so-called pyramids and cross-shareholdings as well as business groups. On the other hand, interlocked directors among firms are known to convey information and power (König & Battiston, 2009, p. 25) and are considered as a primary indicator of connections between two companies (Mizruchi, 1996, p. 271). Outside directors are frequently recruited from the banking, insurance and investment sectors and many of them hold multiple directorships as well as executive positions at their own company (Scott, 1991, p. 182). Personal and capital relations together are often seen as principal control relations surrounding enterprises (Scott, 1991, p. 184). The spread of corporate practices through the director network can have implications for the decision making process (König & Battiston, 2009, p. 25) but it cannot automatically be inferred that there is common behaviour (Scott, 1991, p. 184).

Regarding ownership and finance studies specific to media companies there is a very limited amount of literature[5]. Both media and financial services are very opaque sectors trying to convey as little information as possible about their business interaction networks which means that data is not fully available. This is a setting to apply our novel algorithms to still detect cliques with similar or identical investment structures. Further analysis into the cliques and their communication structures can then provide hints for corporate communication, in particular investor relations. The case study in the subsequent section explores ownership structures of the large media conglomerates using biclique-based algorithms.

4. Case Study: Ownership Structures of Media Companies

This case study tries to close a part of the gap regarding ownership and media studies into

[5] For an overview of previous studies on ownership see (Sánchez-Tabernero & Carvajal, 2002, pp. 12–13) and for studies on finance see (Ozanich, 2006, p. 602).

media companies and investigates the interdependencies of shareholders who have invested in media companies, i.e. the equity side of finance. In most countries ownership of media is restricted (Chambers & Howard, 2006, p. 369), but there could be interdependencies among investors where although they each hold investments below the legally defined thresholds they display common behaviour, e.g. by pooling their voting power or by threatening to sell shares on a larger scale. As research indicates that large-block institutional investors such as large mutual funds, foundations, and pension funds are more likely to influence organisational decision making than other large-block shareholders (Kang & Sørensen, 1999, p. 131) this type of investor is of interest besides banks and insurances.

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An investigation into the ownership and control structures of media companies is of interest for a variety of reasons: the specific nature of media products and services, the existing and emerging social network structures, and the intransparencies of both media industry and financial services.

The media industry provides products and services of a very special nature because they are not only commercial goods but also have a cultural dimension in that they have to respond to value objectives of society which might be set down in a legal framework (Chan-Olmsted, 2006, pp. 2–3). Media companies not only supply the platforms for information distribution and exchange but also most of the content. The combination of control of information access and provision endow them with a rather powerful position. It is therefore feared that concentration of media ownership could have several undesirable consequences for the performance of the media markets such as reduced access to and decreasing diversity of information, slower innovation and increased prices due to lack of competition (Chambers & Howard, 2006, p. 372).

Financial management is a strategic task for media companies, i.e. the acquisition of either equity or borrowed capital. Traditionally a strong equity base has been regarded as a competitive advantage due to the imperfect structures of the financial markets (Radtke, 2010, pp. 83–84). Experience and credence properties[6] of financial services as well as media products and services lead to a double-asymmetry where both partners must rely on previous experience and/or good reputation. Therefore the ability of effective communication in network structures is vital for long-term stability in capital structures because social connections allow companies to obtain secluded information and reduce information asymmetries (Shane & Cable, 2002, p. 380). Consequently, the financial services sector is linked to media through investments into media companies as well as through the interlocking directorships explained above. “(...) the capital intensive nature of the media industry provides finance with a center role in all key decisions” (Rizzuto, 2006, p. 145). Strong and dependable links provide the basis for reliable external finance for the media companies and risk reduction for the financial investors (Shane & Cable, 2002, p. 365).

A theoretical framework from economics used for analysing dependencies between market structure, the behaviour of market participants and the eventual outcomes is the so-called Structure-Conduct-Performance-Paradigm (SCPP). Its hypothesis is that a high seller concentration (structure) negatively affects the industry’s social performance because

[6] Experience goods are goods for which the product or service characteristics, specifically their quality, are difficult for consumers to ascertain in advance but emerge only upon consumption (Bode, 2010, p. 22). A customer can only say whether he/she liked a film after having seen it. For news, quality cannot be fully determined, even after consumption but the recipient must have trust in the provider. Goods of this type are called credence goods. In both cases consumers try to improve their choices by relying on previous experiences or reward good reputation (Dogruel & Katzenbach, 2010, pp. 109–113; Shane & Cable, 2002, p. 380).

companies will set higher prices (behaviour) and thus can earn higher profits. It questions the assumptions of the perfectly competitive market model such as of full transparency of information, free market access and exit as well as a large number of buyers and sellers as being too far from the real world. Therefore ideas associated with imperfect competition are integrated such as limited information, transaction costs, costs of adjusting prices, government actions, and barriers to entry by new firms into a market. The emerging models are then investigated regarding how firms are organized and how they compete.

Although there are various elements determining market structure (e.g. product differentiation or barriers to entry) the case study in its initial stage which is presented in this paper focuses on the structure by looking at aspects of seller concentration[7] on a market which increase if the dominant position of the main players becomes stronger or the absolute number of companies goes down (Sánchez-Tabernero & Carvajal, 2002, p. 15). Media concentration could increase through M&A activities[8] or previously agreed behaviour of several firms etc. Concentration of ownership could also occur through structures on the meta-level where investors hold shares in the same media companies and pool their voting rights to name members of boards of directors and/or to jointly control the decisions of the respective media companies (Sánchez-Tabernero & Carvajal, 2002, p. 27). Their power increases over-proportionally if they can use their formal or informal authority, social influence, and expertise for additional influence on performance (Kang & Sørensen, 1999, p. 121).

For the case study we investigated the relationships of the Top 40 publicly listed[9] media

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[7] Concentration can be analysed from either a market or a company perspective. Market concentration describes the number of firms and their respective shares of the total production (alternatively, total capacity or total reserves) in a market. Market concentration increases if the dominant position of the main players becomes stronger or the absolute number of companies goes down. From the company perspective, the so-called industrial concentration refers to industrial growth of the media groups (Sánchez-Tabernero & Carvajal, 2002, p. 15).

[8] Mergers and Acquisitions. The 1980s and 90s were a time of unprecedented consolidation in the media (Ozanich, 2006, p. 607).

[9] A publicly listed (traded) company is a company that offers its securities (stock/shares, bonds/loans, etc.) for sale to the general public, typically through a stock exchange, or through market makers operating in over the counter markets.

companies and their publicly listed shareholders (158 banks, insurances and other financial investors). For publicly listed companies more data is available as they have more extended reporting requirements regarding their income situation as well as their shareholder structures. However, this does not mean that data is fully available as legal requirements do not request full disclosure and can also differ across countries. Typically shareholdings of less than 5% do not have to be revealed. The data source for our case study was the *Osiris Database* (Bureau van Dijk, 2011).

Affiliation networks of this type can be modelled by bipartite (or two mode) graphs[10] which are comprised of two classes of nodes: actors (in our case media companies) each of whom belongs to one or more groups (in our case financial investors) (Watts, 2004, p. 248). Obviously not all investors hold shares in all media companies, so our initial graph only contains a link between a media company and an investor if a shareholding exists. The existing links were weighed with the percentage of ownership of an investor into a media company. If a percentage was not available an estimate based on historic data was used. Within our large initial graph we searched for sub-graphs where all media companies had exactly the same financial investors. As explained above this is a very difficult search problem in computer science and novel algorithms allowed to actually find the results although some of the data was missing or noisy. One example of a sub-graph is displayed in figure 1. It becomes obvious that it would have been impossible to find it through visualisation in the huge initial graph. Table 1 lists the seven media companies and 31 financial investors of the extracted sub-graph. Among them are well-known participants from both industries that could have a strong interest in coordinated behaviour.

[10] See appendix for additional information on the approach and algorithm used.

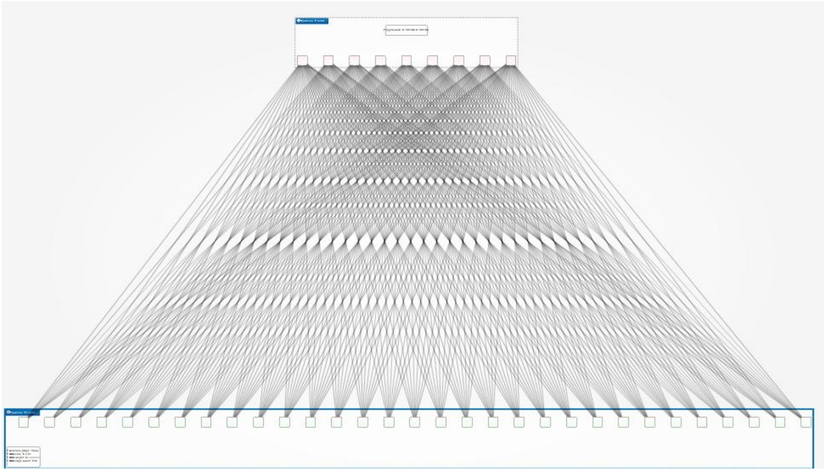

Figure 1: Graph of Quasi-Biclique with Financial Investors all holding Shares in the same publicly listed Media Companies (Data Source: Bureau van Dijk, 2011)

Media Companies (9 companies)	**Financial Investors (via funds, except Mitsubishi) (31 companies)**
McGraw Hill Companies Inc. Discovery Communications Comcast Corporation Cablevision Systems Corporation Time Warner Inc. News Corporation Inc. Viacom Inc. Walt Disney Yahoo Inc.	Blackrock Inc. Deutsche Bank AG State Street Corporation Rhumbline Advisers Limited Partnership Prudential Financial Inc Goldman Sachs Group Inc. T. Rowe Price Group Inc. State of Texas Bank of America Corporation Teachers Insurance & Annuity Association of America Mitsubishi Ufj Financial Group Inc. - Kabushiki Kaiska Mitsubishi Ufj Financial Group FMR LLC AXA Sumitomo Mitsui Trust Holdings, Inc. State of Florida Government of Norway The Vanguard Group Inc. JP Morgan Chase & CO. Power Corporation of Canada Charles Schwab Corporation Regeringskansliet Mizuho Financial Group Janus Capital Group Inc.. State of New York Legal & General Group PLC Geode Capital Mananagement LLC State of California UBS AG Credit Suisse Group AG Northern Trust Corporation Bank of New York Mellon Corporation

Table 1: Example of a Quasi-Biclique with Financial Investors all holding Shares in exactly the same publicly listed Media Companies (Data Source: Bureau van Dijk, 2011)

The next steps in extending the case study will be to investigate the behaviour, for example possible interlocking directorships or coordinated behaviour in the market environment such as enforcing industry standards. Furthermore, an increasing orientation of corporate objectives towards short-term shareholder value could be another indicator of an influence of investors on company decision making as well as changes in news reporting about investors by the detected media companies (Glaum et al., 2003, p. 831). The objective would be to improve previously inconclusive results regarding the influence of ownership concentration and firm performance because they could not sufficiently account for the complex social context and relationships in which ownership occurs (Kang & Sørensen, 1999, pp. 131-3).

From a media management and communication perspective the recommendation is to cultivate investor relations more strongly than in the past. As the company reputation is so vital for the sale of their products and services, the functioning of their strategic networks as well as the stable provision of finance this means corporate communication must be able to fully exploit the network structures, in particular with investors. In crisis situations investors may act and further increase the severity of the situation by selling their shares and in turn damaging the reputation of media companies with their customers leading to a drop in sales.

5. Conclusion

Investigations into the social networks, especially those of companies, can reveal hotspots of people and organizations (central communicators or stakeholders as well as media) that are determining and controlling crucial communication and power structures. Single individuals or sometimes small clusters of people can exercise influence or act as brokers within their social networks by bridging networks that are not directly linked. Therefore, it is not only important to determine these information hubs but also learn more about when, about what and how they share information. The better the information flows are understood, the more adequate corporate communication can devise communication strategies.

Despite its promise, such investigations are largely challenged by the vast complexity of networks that is inherent to the environment in which companies exist. However, the application of the novel network algorithms to social networks relevant for media companies provides a unique opportunity for the extraction of hidden information as they also provide good results for incomplete or partially distorted data sets. It allows to detect attributes social network participants have in common, and thus to better predict their behaviour and potential communication patterns. Results from these algorithms can be used as a starting point for further analysis and interpretation to establish the relevant strategies to both monitor and adequately disseminate information.

6. Appendix: Mining Network Data using Weighted Quasi-Bicliques (Chang, Vakati, Krause, & Eulenstein, 2011)

6.1. Basic Notation and Definitions

Basic Notation

A ***bipartite graph***, denoted by $(U+V,E)$ is a graph whose vertex set can be partitioned into the two independent sets U and V such that its edge set E consists only of edges $\{u,v\}$ where $u \in U$ and $v \in V$.

A **weighted bipartite graph**, denoted by $(U+V,E,\omega)$, is a bipartite graph $(U+V,E)$ with a weight function $\omega \rightarrow [0,1]$.

A **complete bipartite graph** is a bipartite graph for which there exists an edge between any two vertices $u \in U$ and $v \in V$

A **biclique** in G is a pair (U',V') that induces a complete bipartite sub-graph in G where $U' \subseteq U$ and $V' \subseteq V$.

Definitions

A **weighted quasi biclique** in G is a pair (U',V') that almost induces a weighted complete bipartite sub-graph in G where $U' \subseteq U$ and $V' \subseteq V$ depending on defined boundaries of which percentage of links could be missing for a complete biclique.

The **alpha-beta weighted quasi biclique,** denoted as $(a, \beta - WQB)$ is defined as follows:
Let $G := (U+V, E, \omega)$ and $\alpha, \beta \in [0,1]$.
An $a, \beta - WQB$ in G is a non-empty pair (U', V') that is included in (U,V) and satisfies the following properties:

1) $\forall u \in U' : \sum_{v \in V'} \omega(u,v) \geq a \cdot |V'|$
2) $\forall v \in V' : \sum_{u \in U'} \omega(u,v) \geq \beta \cdot |U'|$

The **weight** of an $a, \beta - WQB$ is defined as the sum of the weights of all its edges.

A **maximum weighted** $a, \beta - WQB$ of a weighted bipartite graph $G := (U+V, E, \omega)$ is an $a, \beta - WQB$ of G, the weight of which is at least as much as the weight of any other $a, \beta - WQB$ in G.

6.2. Solving α,β-WQB Problems

Problem 1 [$a, \beta - WQB$ **problem]**
Instance: A weighted bipartite graph $G := (U+V, E, \omega)$, and values $\alpha, \beta \in [0,1]$.
Find: A maximum weighted $a, \beta - WQB$ in G.

Problem 2 [Query]
Instance: A weighted bipartite graph $G := (U+V, E, \omega)$, values $\alpha, \beta \in [0,1]$ and a pair (P,Q) included in (U,V).
Find: The $a, \beta - WQB$ which includes (P,Q) and has a weight greater than or equal to the weight of any other $a, \beta - WQB$ in G which includes (P,Q).

Complexity of the above problems
Both problems are NP-hard.
For the $a, \beta - WQB$ problem there exist a reduction from the *maximum edge biclique problem*

(which is a well known NP-complete problem).

For the Query problem there exists a series of reductions from the *query problem* (which is a known NP-complete problem).

Applicability of weighted quasi bicliques

Quasi bicliques can be used in all these situations where we require the mining of bicliques but the data might be incomplete or noisy.

Examples of applications:

1) Biological interaction networks (e.g. protein – protein interactions)
2) Web interaction networks (e.g. web communities – groups of users interactions)
3) Financial interaction networks (e.g companies – shareholders)

In short, they can be used for all research questions that can be solved by in mining bicliques from bipartite graphs with missing or noisy data.

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